6. HABITAT IMPACTS TO SUMMER CHUM SALMON

6.1. Introduction

This section provides a summary of the overall habitat conditions as they have been determined to affect summer chum salmon recovery. Details of specific habitat conditions will be found in the subsequent sections 7-12 of this Salmon Recovery Plan (SRP). Those sections are devoted to individual conservation units. Section 6 gives a brief overview of general habitat conditions throughout the ESU and discusses particular habitat issues that will need to be addressed to affect summer chum recovery.

Diversity of summer chum salmon is controlled by genetics and habitat. That diversity is manifested by variations in geographic distribution, behavior, morphology and other characteristics. It is reflected in the number and distribution of stocks, and in the expression of multiple life history pathways accommodated by habitat condition. The SRP contends that diversity has decreased, owing to the loss and reduced quality of habitat. Diversity has also been diminished by the recent population declines of summer chum salmon, primarily through the extinction of stocks (see Summer Chum Salmon Conservation Initiative {SCSCI} section 1.7.2), but also potentially by the reduced size of populations. Population size reduction, from historical levels, may have resulted in a decreased distribution within watersheds and nearshore areas. And, this reduction in the range of habitats used may have also decreased the currently available life history pathways. The risk of losing genetic diversity also increases with smaller population sizes.[26]

6.2. Conceptual Life History Of Hood Canal/Eastern Strait Of Juan De Fuca Summer Chum Salmon

Understanding habitat conditions, that are necessary for the persistence and survival of summer chum salmon, necessitates understanding the life history of summer chum salmon. Distribution of the fish, and the life history strategies for both the freshwater and marine phases, can allow a focus for habitat managers. They can determine effective recovery actions, both in terms of location of those recovery actions, and timing of when to effectively implement the actions. Much has been written regarding the life history of Pacific salmon in general, and chum salmon in particular. While much of the information is specific to summer chum salmon, some of the descriptive material is derived from investigations of fall-timed chum salmon. SCSCI section 1.3 (Washington Department of Fish and Wildlife and Point No Point Treaty Tribes 2000) provides a summary of the life history of summer chum salmon and the reader is encouraged to review the SCSCI. SCSCI Appendix Report 3.5 (see WDFW and PNPTT 2000) provides a description of the potential estuarine landscape impacts on summer chum

[26] See McElhany, et. al. (2000) for a more in-depth discussion of diversity.

salmon. Lestelle, et. al. (2005b) provides a more recent summary of the information, much of which was derived from the SCSCI.

Summer chum salmon of Hood Canal and the Eastern Strait of Juan de Fuca are defined as those chum salmon that have an average peak of spawning before November 1 (WDFW and PNPTT 2000).

The following overview, of chum salmon distribution, biology, and life history, is excerpted from Lestelle, et. al. (2005b)[27]. It states, "Throughout their distribution in North America and Asia, chum salmon commonly exhibit both an early and late timing pattern when returning to their natal streams (Salo 1991). Early timed runs are called summer chum, while the late runs are called fall chum. In Puget Sound, the late returning populations are further distinguished as being either fall or winter runs, based on peak return timing (Johnson et al. 1997). NOAA Fisheries has designated Hood Canal and Strait of Juan de Fuca summer chum as an ESU, based on distinctive life history and genetic traits (Johnson et al. 1997). In Hood Canal, eleven streams have been identified as recently having indigenous summer chum (Ames et al. 2000): Big Quilcene River, Little Quilcene River, Dosewallips River, Duckabush River, Hama Hama River, Lilliwaup River, Union River, Tahuya River, Dewatto River, Anderson Creek, and Big Beef Creek. They have also been observed in small numbers on occasion in the Skokomish River in Hood Canal. In the eastern Strait, summer chum populations are recognized in Snow and Salmon creeks in Discovery Bay and Jimmycomelately Creek in Sequim Bay. They have also been reported in Chimacum Creek in Admiralty Inlet and in the Dungeness River.

"Fall chum are distributed much more extensively throughout the Puget Sound region than summer chum. They are located in the same streams where summer chum are produced. The uniqueness of summer chum in Hood Canal and the eastern Strait is best characterized by their late summer arrival to natal streams and their late winter/early spring fry migration to the estuary. Tynan (1997) provides detailed information on return and spawn timing for each population. While spawning varies somewhat between some populations, it typically occurs from late August through late October. Fry emerge from the gravel between early February and May, with peak emergence being March 22 and April 4 for Hood Canal and Strait populations respectively (Ames, et. al. 2000). In contrast, Hood Canal fall chum spawn predominantly in November and December, and fry emerge approximately one month later than summer chum, between late April and mid-May (Koski 1975; Tynan 1997). Summer chum spawn soon after freshwater entry in the lower reaches of the mainstem streams. The use of lower reaches may be an adaptation to the low flow conditions present at arrival time; September is frequently the month of lowest flow in Hood Canal streams. In Big Beef Creek, Koski (1975) reported that the native summer

[27] To view the full document, the reader is encouraged to see Appendix B of this SRP. References cited in this excerpt may be found in the Lestelle et al (2005b) document.

chum salmon population (now extinct) spawned in the lower 0.8 km of the stream, while later timed chum extended their spawning to 6.4 km of stream. Similar spatial patterns of spawning occur in other Hood Canal and Strait streams. In contrast to summer chum, fall chum spawn in side channels, tributaries, and springs, as well as in mainstem creeks and rivers. Fall chum will use reaches or streams with strong groundwater influence, if available (Salo 1991).

"Emerging during the darkness of night, chum fry immediately move downstream, likely entering the stream mouth estuary the same night of emergence within Hood Canal streams (Simenstad 2000b). Transition from freshwater to brackish and saline waters within the estuary can therefore be very brief—less than 12 hours. Emergence and fry emigration to the estuary from a single watershed likely occurs over several weeks, similar to emergence patterns seen for other salmonids. Instream feeding during migration by chum in general is probably insignificant except in very large rivers where spawning migrations are extensive (Simenstad 2000b). Simenstad (2000b) reported that the residence time of chum fry within larger Hood Canal natal subestuaries is likely less than one week, suggesting that it is very brief in the smallest subestuaries. He suggests that fry may be held longer in the larger, more complex subestuaries than in the small or simplified subestuaries because of the better feeding conditions and lower water velocities associated with marshes and dendritic channels. Terrestrial drift insects are often prominent in the diet of chum fry in the inner portions of subestuary deltas and along the large margins of large deltas (Congleton 1979; Mason 1974; Simenstad 2000b). Small subestuaries and tidal marshes appear to be stopover sites for chum fry migrating along the nearshore corridor, moving in with the tide and utilizing both terrestrial and marine based food webs, before moving out again on the receding tide (Mason 1974; Hirschi, et. al. 2003). This pattern of utilization has been observed for chum salmon within Hood Canal (Hirschi, et. al. 2003).

"Upon departing the natal subestuary, chum fry inhabit shallow nearshore areas. For the first few weeks of estuarine life, they have been observed in the top 2-3 centimeters of surface waters and extremely close to shore. A description of early life in waters of Hood Canal is useful here. Ames, et. al. 2000, says that Chum fry arriving in the Hood Canal estuary are initially widely dispersed (Bax 1982), but form loose aggregations oriented to the shoreline within a few days (Schreiner 1977, Bax 1983, Whitmus, 1985). These aggregations occur in daylight hours only, and tend to break up after dark (Feller 1974), regrouping nearshore at dawn the following morning (Schreiner 1977, Bax 1983). Bax et al. (1978) report that chum fry at this initial stage of out-migration use areas predominantly close to shore. Early run chum fry in Hood Canal (defined as chum juveniles migrating during February and March) usually occupy sublittoral seagrass beds with residence time of about one week (Wissmar and Simenstad 1980). Schreiner (1977) reports that Hood Canal chum maintain a nearshore distribution until they reach a size of 45-50 mm, at which time they move to deeper offshore areas. "Within the nearshore corridors, chum fry feed primarily on small crustaceans, such as harpacticoid copepods, and other epibenthic invertebrates, such as small gammarid amphipods (Kaczynski et al. 1973; Healey 1979; Simenstad et al. 1982). Simenstad (2000b) states that their diet is "surprisingly specific", targeting two or three species of harpacticoid copepods (i.e., Harpacticus uniremis and Tisbe sp.). He states that extremely high densities of these organisms often occur in eelgrass beds. This high selectivity for specific copepod species has been found within estuaries between Washington and Alaska (Salo 1991). The period of estuarine residence appears to be the most critical phase in the life history of chum salmon, having a major role in determining the size of the subsequent adult run (Johnson, et. al. 1997). Chum salmon are considered second only to Chinook salmon in dependence upon estuarine waters (Salo 1991). Upon reaching a threshold size, summer chum juveniles entering Hood Canal and Strait of Juan de Fuca estuarine waters appear to begin their migration seaward quite rapidly, with little delay (Tynan 1997). This rapid seaward movement may reflect either "active" migration in response to low food availability or predator avoidance, or "passive" migration, brought on by strong prevailing south/southwest weather systems that accelerate surface flows and move migrating fry northward (WDFW and PNPTT 2000). The southernmost Hood Canal summer chum emigrating fry population may exit the Canal in about two weeks after entering seawater. Summer chum salmon juveniles likely migrate in schools northward along the Hood Canal shoreline and then westward adjacent to the Strait of Juan de Fuca shoreline to reach Pacific Ocean rearing areas.[28]

Based on our understanding of summer chum salmon life history, the SRP will initially focus on those areas that most directly affect survival and persistence of the existing populations, the freshwater habitats (typically lower river spawning areas), and the immediate marine nearshore environs.[29]

6.3. Overview of Habitat Impacts

Three primary factors have combined to cause the decline of summer chum salmon in both Hood Canal and Strait of Juan de Fuca streams (WDFW and PNPTT 2000). They are: 1) climate related changes in stream flow patterns; 2) fishery exploitation, and 3) habitat loss. An unusual feature of the declines is that the summer chum salmon of the two regions (Hood Canal and Eastern Strait of Juan de Fuca) have been affected by similar factors; but the declines have occurred ten years apart (WDFW and PNPTT 2000). The summer chum salmon of both regions have experienced concurrent changes in critical stream flows and

[28] The SCSCI (WDFW and PNPTT 2000) provides a more detailed description of this life history behavior for summer chum salmon juveniles including references to various studies and researchers that have explored these topics. The reader is encouraged to review the SCSCI for more details.
[29] Section 3 of the SRP provides more specific information regarding the schemes the SRP is using to determine the sequence and prioritization for recovery and management actions.

increased fishery exploitation rates. While section 6.3 will focus on region-wide habitat impacts, individual stocks may have been differentially impacted by specific, identified factors for decline. More detailed assessments at the stock, watershed, and conservation unit level are presented in the SRP sections 7-12.

6.3.1. Climate Change and Fishery Exploitation

The long-term loss of habitat productivity and capacity will impact summer chum salmon by lowering survival rates (population resiliency) and reducing potential population size. When Hood Canal/Eastern Strait of Juan de Fuca summer chum salmon began to experience the added pressures from climate change and new fishery exploitation, the populations collapsed. In 1979, summer chum run sizes and subsequent escapements were very low because of the effects of unfavorable stream flows on the 1975 and 1976 brood production (WDFW and PNPTT 2000). This poor performance was evident in chum salmon stocks statewide. The summer chum populations of Hood Canal (with the exception of Union River) were the only chum stocks that did not immediately recover from the low return levels of 1979 (WDFW and PNPTT 2000). WDFW and PNPTT (2000) discusses the potential impacts from climate change and particularly, the possible impacts to stream flows during spawning and incubation (see SCSCI section 2.2.2.4). The co-managers further conclude, however, that "[A]ny analysis of climate change in relation to stream flow and the decline of summer chum salmon populations cannot be isolated from human-caused habitat alterations."

Human induced changes and impacts to Hood Canal/Strait of Juan de Fuca stream ecosystems have potentially diminished the natural resiliency of summer chum salmon habitat, rendering populations more vulnerable to climate shifts. Climate shifts like those observed in the past 30 years, with their associated stream flow changes, likely have posed little threat to summer chum populations before the cumulative effects of habitat changes from human development became manifest. Summer chum salmon persisted long before significant human development.

Net fisheries in Hood Canal, when combined with pre-terminal harvests, began to impose high exploitation rates on summer chum salmon in 1980, contributing to low escapements through the 1980s (see SRP section 4). At the same time, oceanic climate changes influenced regional weather patterns, resulting in unfavorable stream flows during the summer chum salmon egg incubation seasons. Spawning flows also dropped substantially in 1986 (likely climate related), and contributed to the continuing poor status of these stocks. The current low production of Hood Canal summer chum salmon appears to be the result of the combined effects of lower survivals caused by habitat degradation, climate, increases in fishery exploitation rates, and the impacts associated with the releases of hatchery salmonids (WDFW and PNPTT 2000).

The pattern of decline of summer chum salmon in Strait of Juan de Fuca streams was similar to the Hood Canal experience, however, the drop in escapements occurred ten years later, in 1989 (WDFW and PNPTT 2000). The impact of habitat alteration likely had similar negative impacts on stock survivals and resiliency. Eastern Strait of Juan de Fuca summer chum stocks were also affected by a coincidental concurrence of changes in stream flows and exploitation rates. Regional stream flows during the spawning season dropped substantially in 1986, and likely contributed to lower returns beginning in 1989 (WDFW and PNPTT 2000). There were no terminal area harvests of summer chum salmon in this region, however, these fish were harvested in pre-terminal fisheries for other salmon species. In 1989, the pre-terminal exploitation rates increased substantially, reducing the numbers of summer chum salmon escaping to Strait of Juan de Fuca streams (WDFW and PNPTT 2000). The combined effects of reductions in habitat quality, stream flows, and fishery exploitation resulted in low summer chum salmon production in the region.

6.3.2. Habitat Loss and Degradation

Summer chum populations rely on a complex mix of different habitat types, in different seasons, during their various life stages. Spawning and egg incubation occur in freshwater; juveniles rear and find refuge in estuarine deltas and nearshore areas; feeding and growth of adults takes place in the open ocean. Ample, high quality habitat is critical to the recovery of summer chum salmon populations in the Hood Canal and Eastern Strait of Juan de Fuca. Recovery efforts and actions must consider habitat quality and quantity, the fishes' life history diversity, and its population resiliency. The approach of this SRP is to provide for the habitat requirements of each life stage (including adult migration, spawning, incubation and emergence, rearing, and juvenile migration), and for overall life history diversity, to ensure the survival and persistence of summer chum salmon throughout the ESU geographic area.

WDFW and PNPTT (2000) state that survival during the freshwater life history stages is linked to a number of habitat parameters. Those include water quantity (low and peak flows), water quality (primarily temperature), riparian forest conditions (width of riparian forest, age of trees, species composition), sediment conditions (aggradation, degradation, presence of fines), channel complexity (large woody debris quantities, channel condition, amount of side channel habitat), access to habitat, and presence of predators. Most factors are interrelated, as a change in one parameter typically manifests itself in changes to other parameters. For example, reduced channel complexity is closely correlated with high rates of sediment transport and deposition, as well as reduced channel interaction with the associated floodplain.

Survival during adult migration and spawning is largely a result of interactive processes between recruitment of suitable sized gravel, adequate stream flow, water temperature, and channel complexity such as the presence of large woody debris to create holding pools and provide cover from predators. Conditions conducive to successful egg incubation and rearing include: 1) the presence of adequate large woody debris (LWD) to reduce scour of incubating eggs and moderate peak winter flow velocities; 2) the absence of excessive fines within spawning gravel; 3) stable channel configuration, and; 4) access to floodplain and offchannel areas. The excavation of redds by spawning adults may also contribute to streambed surface coarsening and sorting, and thereby reduce scour of incubating salmon embryos during winter high flow events. Processes within the freshwater environment can also influence the condition of subestuarine and nearshore environments. Hydrologic regimes, as well as transport and supply of LWD, sediment, and nutrients from watersheds, have a direct impact on both the quantity and quality of subestuarine and nearshore habitats used by summer chum (WDFW and PNPTT 2000).

Critical rearing and transition environments for summer chum salmon exist in the multitude of subestuary deltas of Hood Canal and the eastern Strait of Juan de Fuca. These areas support a diversity of habitats including tidal channels, mudflats, marshes and eelgrass beds. WDFW and PNPTT (2000) further states, "The importance of subestuaries for summer chum is linked to the placement of diverse, productive habitats in areas where summer chum fry are making dramatic transitions in physiology, feeding, and predator avoidance strategies. Diffuse networks of distributary channels allow fry migrating down rivers to access shallow-water wetlands such as tidal freshwater sloughs and salt marshes. In salt marshes, complex, branching networks of tidal channels serve as opportune feeding areas, as well as refugia from predators and migratory corridors linking the marsh to riverine and marine realms as well as other estuarine habitats. Juvenile chum salmon feed on invertebrate prey that depends on detritus. Marshes, mudflats, and riparian forests supply detritus to tidal channels, algal mats, and eelgrass meadows where summer chum and their invertebrate prey concentrate. Tidal channel and subtidal habitats provide resting and hiding places for summer chum, and expand salinity gradients to ease fish transition between fresh- and saltwater. The seasonal pulse in production of shallow-water invertebrate prey in subestuaries is thought to be an important resource for juvenile chum salmon entering marine waters and emigrating in April and May. Their use of subestuaries during the springtime period when productivity is increasing enables them to grow quickly and attain a large size to help them escape predation once they begin their migration through the open, deepwater of Hood Canal and Strait of Juan de Fuca. Earlier-migrating (February-March) summer chum salmon juveniles may benefit less from these areas, as available information indicates that their subestuary residence time, and growth accrued in those areas, is less than the residence time and growth observed for fall chum salmon juveniles (Tynan 1997)."

Understanding impacts to habitat requires an understanding of how summer chum salmon life history is linked to particular habitats and the ecological processes that sustain these habitats. SCSCI section 3.4.2 (WDFW and PNPTT

2000) provides more details regarding the ecological context of habitats and summer chum salmon survival and persistence. In general, the SRP focuses on the habitat factors that have been identified as contributing to the decline of summer chum salmon. These are listed in Table 6.1.

Table 6.1. Significant habitat factors that contribute to the decline of summer chum salmon in Hood Canal and the eastern Strait of Juan de Fuca (modified from WDFW and PNPTT 2000).

Habitat factors for decline	Life stage most affected	Impacts
Loss of channel complexity (large woody debris, channel condition, loss of side channel, channel instability)	Spawning and incubation	-Reduced holding pool quality and availability renders adults vulnerable to predation and harassment; reduced channel complexity increases frequency and severity of redd scour -Low levels may increase redd scour, contribute to channel instability, and limit availability of adult holding pools -Increased substrate mobility resulting in redd scour and entombment or de-watering of redds -In-channel structures obstruct or impede adult passage; tidegates and dikes limit juvenile access to subestuarine rearing and feeding habitats -Floodplain and wetland loss concentrates flood flows in main channel, increases peak flow volumes, and results in increased redd scour; loss of wetlands reduce summer low flow volumes -Limits adult holding areas, and confines spawning to main channel areas where redds are prone to scour
Altered sediment dynamics	Spawning and incubation	-Suffocation of developing embryos, entombment of fry in the gravel bed, compaction and cementing of spawning beds -Channel aggradation leading to egg/fry entombment, redd dislocation
Riparian degradation	Spawning and incubation	-Removal and modification of native riparian forests increases water temperatures, reduces stability of floodplain landforms, and reduces LWD recruitment to stream channels -lack of LWD Low levels may increase redd scour, contribute to channel instability, and limit availability of adult holding pools
Estuarine habitat loss and degradation (diking, filling, log storage, road causeways)	Juvenile rearing and migration, adult migration	-Dikes, ditches, and road causeways eliminate marsh habitats, limit tidal circulation, and reduce estuarine productivity -Bulkheads eliminate natural sediment sources and contribute to coarsening of nearshore substrates, which reduces or eliminates eelgrass habitats used by chum fry

Table 6.2, taken from Lestelle, et. al. 2005b (see Appendix B), generally describes the conclusions about the primary issues affecting chum salmon performance in the marine waters of Puget Sound, with a particular focus on Hood Canal and the eastern Strait of Juan de Fuca.

Table 6.2. Conclusions regarding the most important issues affecting chum salmon performance in marine areas within the Puget Sound region with emphasis on Hood Canal (from Lestelle, et. al. 2005b).

Issue	Conclusions	Life stages affected
Estuarine/marine survival		
Relative survival between summer and fall chum	• Hood Canal summer chum survive on average at approximately 1/3 the rate of fall chum currently • Historically, difference in survival between the races in Hood Canal was less than seen in recent decades due to more productive forage areas within the shallow nearshore zone and in interspersed subestuaries	Small fry <60 mm
Forage availability		
Prey within subestuaries	• Both terrestrial and aquatic based prey are important within subestuaries • Subestuaries are important "stop-over" feeding areas for chum fry migrating along the nearshore shoreline • Prey availability within subestuaries is related to riparian conditions within the subestuary and the lower portion of the adjoining freshwater system and to adjacent wetlands, marshes, and mudflat • Relative amounts of detrital input to subestuary systems are important to overall system productivity • Land uses within and adjoining subestuaries that result in diking or disconnecting wetlands, sloughs, and secondary channels from main channels will reduce amounts of prey • Subestuaries that have high forage availability will hold fry longer and promote rapid growth and facilitate transition to salt water	Small fry <55-60 mm
Terrestrial based prey within shallow nearshore environment	• Riparian zone of the shoreline can be an important source of prey • Land uses that remove riparian vegetation will reduce inputs of prey to the nearshore environment	Small fry <55-60 mm

Epibenthic prey within shallow nearshore environment	• Epibenthic zooplankton, particularly some species of harpacticoids, are an especially important source of food to small fry • Within year pattern of abundance can vary but generally follows a predictable pattern, peaking prior to the neritic zooplankton peak • Abundance of preferred species varies by month and tends to peak prior to peak abundance of neritic zooplankton • Abundance of preferred species is subject to being heavily cropped by juvenile chum • Eelgrass meadows are major production areas of epibenthic prey for chum fry and provide important feeding areas • Epibenthic organisms are more abundant along beaches less exposed to wave action • Forage availability in bays and segments of Hood Canal and Puget Sound is related to detrital inputs from eelgrass, marsh, and adjoining watersheds; eelgrass is the major source of detritus in many areas of Hood Canal • Migration rate of chum fry is strongly influenced by forage availability; abundant prey slows migration rate for feeding, promoting rapid growth; scare prey accelerates migration in search of preferred prey • Shift to neritic life style (associated with deep water) is accelerated by abundant epibenthic prey; shift is slowed by scarce epibenthic prey • Summer chum are not as adapted to delaying finding good forage as fall chum because of less lipid reserves due to delayed emergence from spawning beds • Shoreline development that results in deepening of existing shallow water areas, coarsening of substrates from sand or mixed-sand to cobble, and docks and piers will reduce eelgrass abundance and associated epibenthic prey production	Small fry <55-60 mm
Neritic prey within deepwater areas of Puget Sound complex (including Hood Canal and Strait of Juan de Fuca)	• Neritic zooplankton are more abundant and uniform in distribution within the inland sea/estuarine complex of Puget Sound (including SJDF) than in the open ocean • Within year pattern of abundance can vary but generally follows a predictable pattern; interannual variability in abundance pattern can have a strong effect on interannual survival of chum fry • Peak abundance tends to follow peak abundance of inshore epibenthic prey • The PDO can have a strong influence on the abundance and timing of zooplankton within the SJDF but mechanisms are complex involving ecological interactions; generally, the recent regime shift has been favorable to early marine survival of chum	Large fry (subyearlings) >55-60 mm

Neritic prey within the coastal waters of North Pacific (outside Strait of Juan de Fuca)	• The PDO can have a strong influence on the abundance and timing of zooplankton within the zone but mechanisms are complex involving ecological interactions; generally, the recent regime shift has been favorable to early marine survival of chum	Large fry (subyearlings) >55-60 mm
Current outflow velocities		
Flow velocities within subestuaries	• High flows during fry outmigration from natal streams will tend to push fry through the subestuary unless suitable refuge or slow water areas exist • Accelerated emigration out of natal subestuary by high flows is disadvantageous to fry survival because it results in sudden, abrupt changes in habitat types experienced by newly emerged fry and exposes them to greater predation risk in deep water when pushed out beyond the delta face • Land uses that accelerate spring runoff or reduce refuge sites in subestuaries from high flows will result in faster emigration rates from natal subestuaries and reduced survival	Small fry <55-60 mm
Surface outflow velocities within the nearshore zone	• Small fry will be moved out of an area faster when relatively high surface outflow velocities occur compared to when low velocities predominate • Relatively rapid, passive movement from nearshore areas will generally be unfavorable to survival because it diminishes feeding opportunities on epibenthic prey, exposing fry to a greater array of predators per unit of time; summer chum have less lipid reserves than fall chum upon entry into the nearshore environment, making them less adapted to a forced, extensive migration from an area as Hood Canal • Shoreline development that results in reduced epibenthic prey abundance will exacerbate the effects of high surface outflows on fry survival because it would diminish opportunities for forage and growth upon arrival to the nearshore environment • Surface outflow velocities in Hood Canal and southern Puget Sound vary both intra- and interannually due to variability in runoff and wind; velocities tend to be greatest in late and early spring • The relative contribution of water surface outflow velocities to diminished marine survival of Hood Canal summer chum compared to fall chum is less than the contribution of poor forage availability (based on weight of evidence considering findings both in Hood Canal and Nanaimo estuary)	Small fry <55-60 mm

Cover and structure, habitat diversity		
Subestuaries—natal and non-natal	• Complexity of channels and structure within natal subestuaries provides refuge from high flows and predators; structure in non-natal estuaries provides refuge from predators • Interspersed subestuaries and tidal marshes along the nearshore shoreline provide "stop-over" feeding sites, predator refuge, and more effective transitioning from freshwater to saltwater conditions	Small fry <55-60 mm
Shallow nearshore	• Shallow beaches provide predator refuge for small fry migrating along shoreline • Eelgrass provides habitat structure for predator refuge for small and larger fry • Kelp forests provide habitat structure for predator refuge for small and larger fry • Areas of low wave exposure and calm water provide bioenergetically preferred feeding sites • Land uses and shoreline development that steepen beaches, coarsen substrates, eliminate or reduce eelgrass or kelp will reduce the quality of the nearshore environment for small fry	Small fry <55-60 mm
Ecological interactions		
Competition – interspecific competition with wild fish	• Potential for competition for food between summer and fall chum fry is small due to timing differences in outmigrations • Potential for competition for food between summer chum and Chinook, coho, steelhead, and cutthroat populations is small due to timing differences in outmigrations and differences in habitat utilization (potential is greatest with Chinook for species listed); potential for competition between fall chum and hatchery Chinook is somewhat greater than for summer chum • Potential for competition for food between both summer and fall chum and pink salmon is high during strong pink abundance years; chum fry behavior is changed when pink are abundant	All size classes of subyearlings
Competition –with hatchery fish[30]	• Potential for competition for food between summer chum and hatchery chum can be substantial due to the possibility for very large numbers of hatchery fish • Potential for competition for food between summer chum and hatchery Chinook, coho, and steelhead is small due to timing differences in outmigrations and differences in habitat utilization (potential is greatest with Chinook for species listed) • Potential for competition for food between both summer and fall chum and hatchery pink salmon is high where large numbers of the latter are released	All size classes of subyearlings

[30] It should be noted that measures are implemented in all regional hatchery operations to delay fish releases until after the majority of summer chum have emigrated seaward. This measure reduces the likelihood for interactions, and including competition for food resources and predation, that may adversely affect summer chum salmon.

Predation on chum fry	• Potential for predation effects on chum fry by wild cutthroat, steelhead, coho, and Chinook can be high when these populations of other species are abundant; cutthroat are known to be particularly effective predators on chum fry • Potential for predation effects on chum fry by hatchery cutthroat, steelhead, coho, and Chinook can be high when hatchery releases of these other species are large • Potential for predation by seabirds, marine fish, and marine mammals is generally relatively low, though unusual concentrations of seabirds and certain species of marine fish can cause high predation	All size classes of subyearlings
Predation on chum adults	• High concentrations of marine mammals (seals, sea lions, and orcas) can cause high predation losses on schooling adult chum	Adult fish
Obstructions to access within subestuaries		
Barriers to juvenile fish passage	• Tidal gates and other impediments to free movement by juvenile chum can block access to blind channels and off-channel sites within subestuaries	Small fry <55-60 mm

6.4. Low Dissolved Oxygen and Summer Chum Salmon

Low dissolved oxygen has been shown to negatively affect freshwater salmon egg incubation and fry emergence. In contrast, little is known regarding the potential impacts on summer chum salmon from incidents of low dissolved oxygen in marine waters. Over the past several years, the marine waters of Hood Canal have been experiencing hypoxia (oxygen concentrations less than 3 mg/l) and even anoxia (oxygen concentrations less than 1 mg/l) with increasing severity, duration and extent. In addition, there have been three extreme events in the last three years. During these extreme events, there has been mortality of marine organisms, including crabs, shrimp, other invertebrates and several species of fish. There has been no documentation of mortality to salmon, either juveniles or adults.

Despite the lack of evidence of direct salmon mortality, there is a great deal of concern for sub-lethal detrimental effects on salmonids from the low dissolved oxygen conditions in Hood Canal. The range of potential effects includes physiological or behavioral effects, negative impacts from aquatic ecosystem changes, and reduction of fitness. If there are some negative impacts from the low dissolved oxygen conditions on Hood Canal Summer Chum salmon, it could contribute to further population declines, or limit recovery potential.

The potential negative effects from the low dissolved oxygen conditions on Hood Canal Summer Chum salmon have not yet been tested or demonstrated. This is an important component of the Hood Canal Dissolved Oxygen Program Integrated Assessment and Modeling Program (HCDOP-IAM). The HCDOP-IAM is monitoring, modeling and testing hypotheses to determine the causes of the low dissolved oxygen, the potential solutions, and the ecological impacts from the condition.

Until the HCDOP-IAM, and others, have fully assessed the impacts from low dissolved oxygen conditions on salmonids in Hood Canal, there can only be supposition about the range of possible effects. Some of those possible impacts could be:

For juvenile summer chum salmon:

- Not being able to find adequate food, as the aquatic invertebrate population may be reduced from low dissolved oxygen concentrations;
- Being exposed to oxygen conditions at levels that are lower than optimal. This could cause physiological stress and reduction in overall fish health;
- Behavioral modifications to reduce exposure to low dissolved oxygen conditions might also remove the juveniles from their preferred habitat and reduce growth and fitness;
- Reduced available habitat, because of the amount of water column containing low dissolved oxygen, could increase the likelihood of mortality from predation; and
- Potential for direct mortality of migrating summer chum salmon.

For returning adult summer chum salmon could include:

- Not being able to find adequate food, as the forage fish populations may be negatively impacted by low dissolved oxygen conditions;
- Being exposed to oxygen conditions which are lower than optimal. This could add physiological stress, reduced fitness and potentially reduced fecundity;
- Reduced habitat overall, increasing competition for available food; and
- Potential for direct mortality of migrating summer chum salmon.

At this time the SRP defers to the process of the HCDOP-IAM and the HCCC's Low Dissolved Oxygen Program to address the issue of low dissolved oxygen in the hood Canal watershed.[31]

6.5. Conclusions

As reported in SRP sections *4-Harvest Impacts to Summer Chum Salmon* and *5-Hatcheries' Impacts to Summer Chum Salmon*, initial remedies to stem the decline of summer chum salmon, and augment its recovery, have included adjustments to harvest management regimes and the institution of supplementation programs. The harvest management and hatchery

[31] More information regarding the efforts directed at the Hood Canal low dissolved oxygen situation can be found at: http://www.wa.gov/hccc/water.htm

supplementation actions implemented in the region have been integrated with commensurate habitat restoration and protection activities. These habitat restoration and protection actions have been implemented reserve critical spawning, incubation, migration, and rearing habitats for use by the summer chum salmon populations benefiting from harvest protection, and produced through the supplementation programs. At the southern terminus of the range of summer-run chum salmon, these populations represent a unique and significant component of regional biological diversity worthy of full protection and recovery (Johnson et al. 1997). The distinctiveness of these populations is tied, at least in part, to the ecological setting of the Hood Canal and eastern Strait of Juan de Fuca. Further work focused on these aspects of summer chum salmon habitat is the subject of this SRP and, in particular, the following sections 7-12.